CAMSHAFT DESIGN FOR A SIX-STROKE ENGINE

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ABSTRACT

An internal combustion engine generally utilizes a conventional four stroke process including an intake stroke, compression stroke, expansion stroke, and exhaust stroke and in addition to this four stroke process, adds a secondary process having two additional strikes for scavenging process employs a fresh air intake stroke and a fresh air exhaust stroke to exhaust any remaining burnt and unburnt gases from the combustion chamber. A six-stroke internal combustion engine with reciprocating pistons wherein the six strokes are the admission of air, the first compression accompanied or followed by a possible cooling, a second compression followed by a combustion, the first expansion producing also a usable work and finally the discharge of the combustion gases, this engine, whose combustion is either with gasoline version or diesel version will included preferably a multiple of five non-uniform cylinders, and will have an energy efficiency of up to 30% higher than that of a four-stroke internal combustion. This study was focused to fabricate the six-stroke engine camshaft by using the variety machining such as conventional lathe machine, milling machine and EDM wire cut. This also limited to the modelling of the camshaft using computer aided design (CAD) and computer aided manufacturing (CAM). At the end of the study, there have results and discussions about camshaft problem and measured stress that exert to the camshaft. Result are taken from the different material which is mild steel (AISI 1080) and stainless steel (AISI 202). Data showed that stainless steel is greater than mild steel as a conclusion.

ABSTRAK

Enjin pembakaran dalaman amnya menggunakan proses konvensional empat lejang termasuk strok pengambilan, lejang mampatan, lejang pengembangan dan lejang ekzos dan tambahan kepada proses empat lejang ini, menambah satu proses sekunder yang mempunyai dua proses tambahan untuk mengaut proses menggunakan pengambilan udara segarstrok dan ekzos udara segar lejang ekzos di mana-mana baki gas terbakar dan tak terbakar dari kebuk pembakaran. Sebuah enjin enam lejang pembakaran dalaman dengan omboh salingan di mana enam lejang adalah pengakuan udara, pemampatan pertama yang disertai atau diikuti dengan penyejukan yang mungkin, mampatan kedua diikuti oleh pembakaran, pengembangan pertama menghasilkan juga kerja yang boleh diguna dan akhirnya pelepasan gas pembakaran, enjin ini, yang pembakaran sama ada dengan versi petrol atau diesel versi termasuk sebaik-baiknya yang dibahagikan lima silinder tak seragam, dan akan mempunyai kecekapan tenaga sehingga 30% lebih tinggi daripada empat-lejang enjin pembakaran dalaman. Kajian ini telah memberi tumpuan untuk mmembuat camshaft enam lejang dengan menggunakan pelbagai mesin seperti mesin larik konvensional, mesin pengisar dan potong wayar EDM. Ini juga terhad kepada pemodelan camshaft dengan menggunakan rekabentuk bantuan komputer (CAD) dan pembuatan terbantu komputer (CAM). Pada akhir kajian ini, ada keputusan dan perbincangan mengenai masalah camshaft dan tekanan yang diukur . Keputusan yang diambil dari bahan yang berlainan yang merupakan keluli ringan (AISI 1080) dan keluli tahan karat (AISI 202). Data menunjukkan bahawa keluli tahan karat adalah lebih baik daripada keluli lembut sebagai kesimpulannya.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

The term six stroke engine describes two different approaches in the internal combustion engine, developed since the 1990s, to improve its efficiency and reduce emissions. In the first approach, the engine captures the waste heat from the four stroke Otto cycle or Diesel cycle and uses it to get an additional power and exhaust stroke of the piston in the same cylinder. Designs either use steam or air as the working fluid for the additional power stroke. As well as extracting power, the additional stroke cools the engine and removes the need for a cooling system making the engine lighter and giving 40% increased efficiency over the normal Otto or Diesel Cycle. The pistons in this six stroke engine go up and down six times for each injection of fuel. These six stroke engines have 2 power strokes: one by fuel, one by steam or air. The currently notable six stroke engine designs in this class are the Crower's six stroke engine, invented by Bruce Crower of the U.S.A; the Bajulaz engine by the Bajulaz S A company, of Switzerland; and the Velozeta's Six-stroke engine built by the College of Engineering, at Trivandrum in India.

The second approach to the six stroke engine uses a second opposed piston in each cylinder which moves at half the cyclical rate of the main piston, thus giving six piston movements per cycle. Functionally, the second piston replaces the valve mechanism of a conventional engine and also it increases the compression ratio. The currently notable six stroke engine designs in this class include two designs developed independently: the Beare Head engine, invented by Australian farmer Malcolm Beare, and the German Charge pump, invented by Helmut Kottmann.

Thermal comfort of human being is highly associated with the environment and physical appearances of each individual. Measurement of thermal comfort must be given attention to give comfort for workers in industries. The factors of environment give the effect to the health, comfort and performance of the workers. The productivity will increase as the workers feel comfortable with working environment.

1.2 PROBLEM STATEMENT

Six stroke cylinders give a positive effect on the engine performance. In order to improve the efficiency, the camshaft of the engine must be modified and differ with four-stroke engine. In this study it focuses the cam lobe at the intake and exhaust flow.

1.3 OBJECTIVE OF STUDY

The objectives of this study are:

a) To design and analyze the camshaft that can be work with six-stroke engine.
b) To fabricate the camshaft by using CNC machine.

1.4 SCOPE OF STUDY

Basically the scope of the project is functioning as a guidance to achieve the objective. This study is limited to the modelling the camshaft of six-stroke engine using computer aided design codes (CAD). Thus for the fabrication, it will use the computer aided manufacturing (CAM) and work with CNC machine. After fabrication of the camshaft have been done, then analysis using FEA Algor used to analyze the stress on the camshaft.

1.5 STRUCTURE OF REPORT

This report is consists of five chapters. The first chapter is introduction about the research study. It includes the background of study, problem statement, objectives, scopes, and the structure of report.

Next chapter focuses on the literature review based on the previous studies of six-stroke engine. Besides that, this chapter includes the study on internal combustion engine that have been related to the engine, the stroke of the six-stroke engine and global warming up that reduced by using the six-stroke engine. So, this chapter has major influences to increase better understanding on this research study and is very helpful to design the methodology of study.

Chapter 3 describes the methodology of the measurement at selected materials. The flow chart of this research is presented with potential arising issues with the preventive action plans. The methods and procedures are described in general. The location of studies and details of subjects involved in this study are explained. Besides that, the details of instruments and machining used and the steps on utilization of the measurement devices are briefly described. Other than that, the data analysis method is also explained at the end of this chapter.

The results and discussions are presented in next chapter. The measured stresses of the camshaft included von mises stress, minimum principal direction stress, maximum principal direction stress and the best material must be chose. Finally, the outcome of this study was compared between mild steel (AISI 1080) and stainless steel (AISI 202).

The final chapter of this thesis consists of conclusion of this research study. The overall combustion engine been ascertained with some recommendation for improvements proposed.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

In this chapter, there were explanation about history of four strokes and six stroke engines included the basic of internal combustion engine. It also has the information about green technology that avoids the global warming up. Graph attached to give a model of illumination for both stroke.

2.2 INTERNAL COMBUSTION ENGINE

An engine is a device which can transforms one form of energy into another form. However, while transforming energy from one form to another, the efficiency of conversion plays a significant role. Normally, most of the engines convert thermal energy into mechanical work and therefore they are called heat engine.

Heat engine is a device which transforms the chemical energy of a fuel into thermal energy and utilizes the thermal energy to perform useful work. Thus, thermal energy is converted to mechanical energy in a heat engine. Heat engines can be classified into two categories which is internal combustion engines (IC engines) and external combustion engine (EC engines).

2.3 SIX-STROKE ENGINE

The six-stroke engine is a type of internal combustion engine based on the four-stroke engine, but with additional complexity intended to make it more efficient and reduce emissions. According to its mechanical design, the six-stroke engine with external and internal combustion and double flow is similar to the actual internal reciprocating combustion engine.

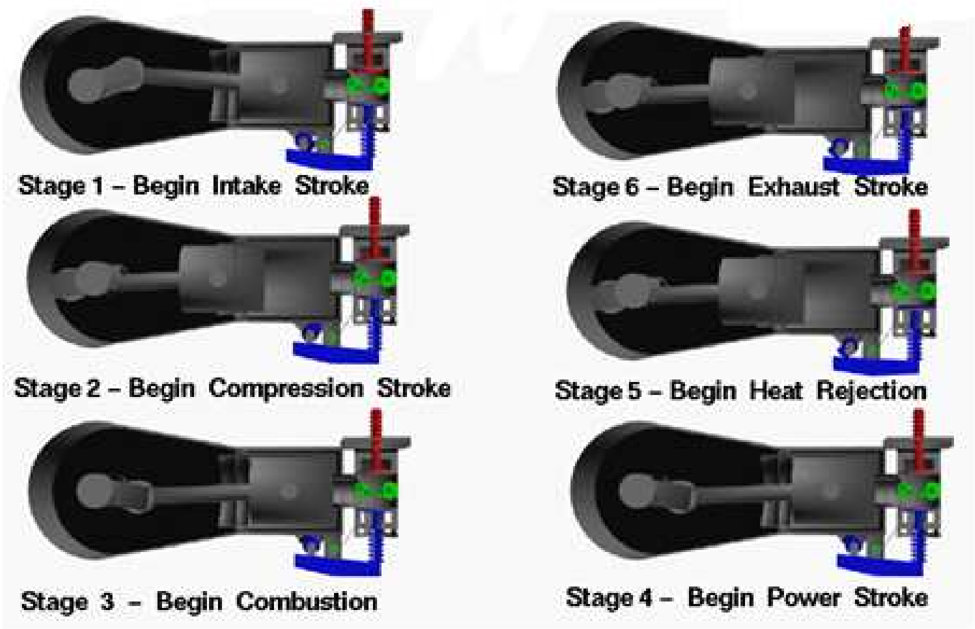

Figure 2.1: Six-stroke engine

Source: NASA

2.4 ADDITIONAL STROKE

To summarize in graphical form on Figure 2.3, there were representative valve lifts and resultant representative combustion chamber pressure traces are superimposed versus crank angle where the proposed exhaust recompression and water injection are explicitly shown.

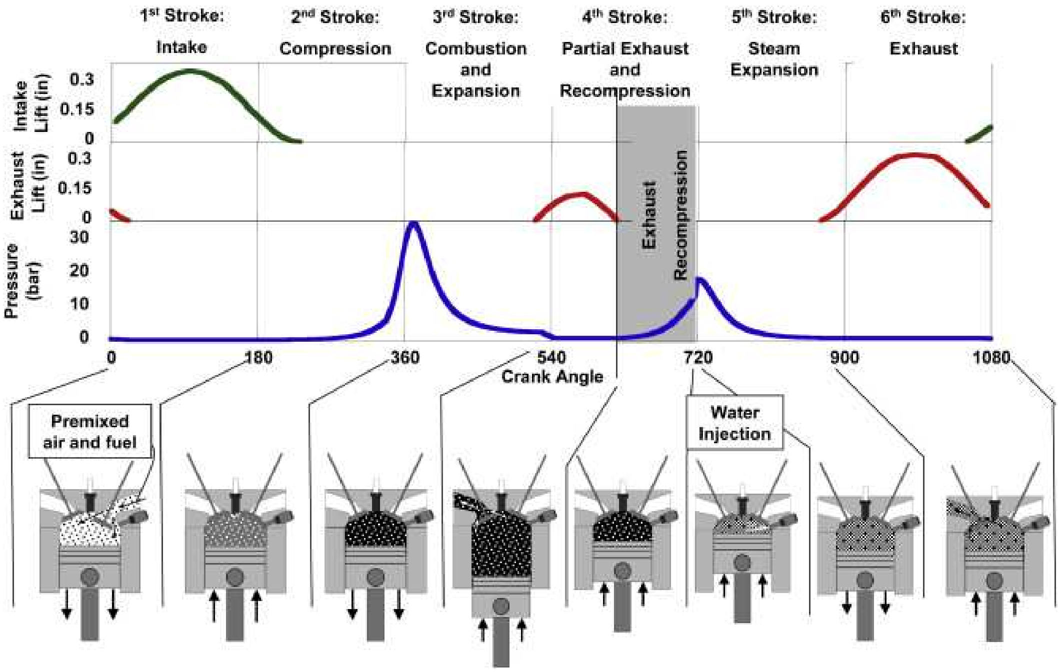

Figure 2.2: Example of exhaust valve events and cylinder pressure for the six-stroke cycle

Source: Hardenberg and Horst O. (1999)

2.4.1 Recompression

An additional assumption that the recompression process is isentropic from State 1 to State 2 yields the additional state property required by the State Postulate of Thermodynamics for a simple compressible system to determine completely the thermodynamic properties at State 2. The work required by the recompression process is thus known for a given crank angle closing.

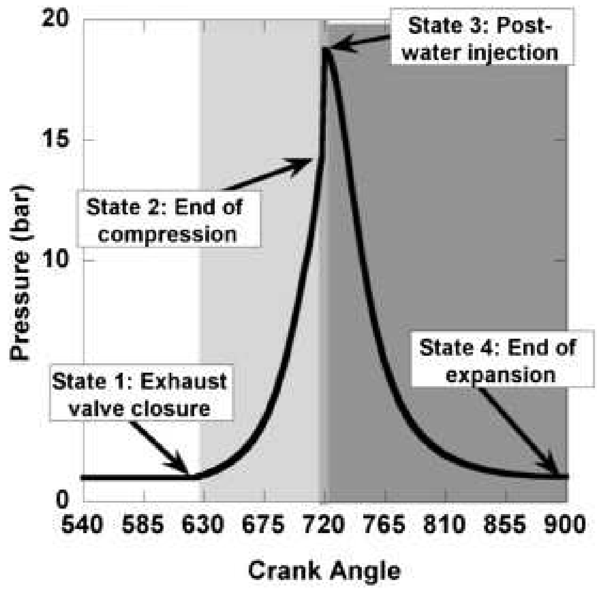

Figure 2.3: Pressure trace schematic for exhaust recompression and steam injection showing thermodynamic states

Source: Merriam-webster.com. (2010)

2.4.2 Water Injection

The identity of mass conservation was employed to equate the mass at State 3 to the mass at State 2 and the mass of the injected water. Now that the two properties of internal energy and specific volume are known at state point 3, the thermodynamic state is uniquely determined. Thus the temperature and pressure at the start of the additional power stroke are known.

2.4.3 Additional Power Stroke Expansion

Because there is no mass flow across the combustion chamber control volume during the expansion process and assuming that the recompression process is adiabatic. An additional assumption that the expansion process is isentropic from State 3 to State 4 yields the additional state property required by the State Postulate to determine completely the thermodynamic properties at State 4. The work output from the expansion process can be calculated.

2.4.4 Effect of the additional two strokes

The net work is the expansion work less the recompression work. The net mean effective pressure (MEP) of the early exhaust valve closure and water injection (the fourth and fifth strokes) is then determined by dividing the expansion work of the fifth stroke less the compression work of the fourth stroke by the displacement volume. Although having the units of pressure, the MEP is a measure of the performance of any engine irrespective of size or volumetric displacement. Condensation during an expansion is generally undesirable because of potential equipment damage due to droplet erosion and also because of the resultant decrease in specific volume. An increase in specific volume results in desirable expansion work.

2.5 SIX-STROKE ENGINE REDUCING GLOBAL WARMING UP

2.5.1 Global Warming

Global warming refers to the rising average temperature of Earth's atmosphere and oceans and its projected continuation. In the last 100 years, Earth's average surface temperature increased by about 0.8 °C with about two thirds of the increase occurring over just the last three decades. Warming of the climate system is unequivocal, and scientists are more than 90% certain most of it is caused by increasing concentrations of greenhouse gases produced by human activities such as deforestation and burning fossil fuel. These findings are recognized by the national science academies of all the major industrialized countries.

2.5.2 Six-stroke Prevents Global Warming

Researcher had state that with an innovative six-stroke engine, the engine shows 40% reduction in fuel consumption and dramatic reduction in pollution. Its specific power is not less than that of a four-stroke petrol engine. The engine can run on almost any fuel, petrol and diesel to LPG. An altered engine shows a 65% reduction in CO pollution when compared with the four stroke engine that was used to develop the Six-Stroke engine.

2.5.3 Six-Stroke Operating With Hydrogen

There are no prospects for engines using hydrogen as fuel to be put to practical use due to significant small output, knocking, and backfire. An object of the present invention is to obtain a stable automobile engine at high drive that can be commercially put to practical use. A hydrogen-only 6-stroke engine realizing high output by 6-strokes for premixing two to seven atmospheric pressure or high pressure hydrogen and air at equivalent weight, spraying the pre-mixture into a cylinder cooled by filling the cylinder with cold air in advance, spraying, compressing, and exploding the mixture, discharging the mixture from a lower exhaust hole, and discharging remaining waste gas from an upper exhaust hole is proposed.

A hydrogen-only 6-stroke engine for spraying oil or emulsion while charging with positive static electricity at high pressure by an injector spark plug arranged at an upper lid in a cold air suction stage of a first stroke, thereby adsorbing the oil or the emulsion to an in-cylinder wall and an auxiliary at the upper lid of negative pole.

A hydrogen-only 6-stroke engine including an injector spark plug having a function of an injector and a spark plug through a hole at an upper lid, in which a metal rod having a needle pin at a distal end is inserted to a hollow metal tube with a spray hole at a lower end, a fixture at an end of the metal rod is hit by soft iron tube that raises and lowers the hollow metal tube and the needle pin by the magnetism of a solenoid coil to raise and lower or open and close the needle pin, oil or emulsion injected at 50 to 100 atmospheric pressure from the upper part of the metal tube is sprayed into the cylinder, high voltage of an anode is applied through the upper part of the metal tube, and spark is generated by an instruction of an ECU.

2.6 MODIFICATION OF FOUR-STROKE TO SIX-STROKE ENGINES

There have some parts required modification such as camshaft, crank to camshaft ratio and water injection. A camshaft is a rod or shaft to which cams are attached. Cams are non circular wheels, which operate the cylinder valves of an internal combustion engine. The camshaft is also used to operate other gear-driven engine components. Camshaft design can determine whether the camshaft can help the engine produce heavy torque or higher RPMs. The cams on the camshaft operate the intake and exhaust valves of the engine.

The original angular speed of the camshaft is one-half that of the crankshaft, such that the camshaft rotates once for every two revolutions (or four strokes) of the crankshaft. The six stroke camshaft has been designed to turn one revolution every three revolutions (or six strokes) of the crankshaft. The six stroke design does not use the existing spur gears, but has straight tooth gears on all three shafts. The reduction ratio has been determined to be a 29-58 tooth pair of gears for a 1:2 reduction between the crankshaft and the reduction shaft and 20-30 tooth pair of gears for a 2:3 reduction between the reduction shaft and the camshaft. This gives an overall gear reduction of 1:3 between the crankshaft and the camshaft.

Integral to the design of the six stroke engine is the injection of water into the cylinder. Since the six stroke design does not include a camshaft, the water injection must be electronically controlled. The water injection system consists of three main components, the injector, the water pressurizing system, and the electronic control system.

2.7 CAMSHAFT PARTS

There have variety parts of the camshaft such as main journal, lobes, and ends. The Main Journals hold the cam in place as it spins around. Cam bearings are placed around the main journals to prevent the cam from damaging the block in case of malfunction in the engine.

The lobes create the cam's lift and duration. Lift is the distance the valve is open and duration is how long the valve will stay open. An example would be cams have a .429 intake lift and a .438 exhaust lift and duration of 203 degrees on the intake and 212 degrees on the exhaust. The intake valve would be lifted .429" and stay open for 203 degrees of the cams rotation and the exhaust would be lifted .438" and stay open for 212 degrees of the cams rotation. The rear end of the cam has a gear that turns the distributor of the engine keeping the ignition timing in tune with the rest of the engine, while the front of the cam bolts up the timing chain keeping the cam timed with the crankshaft.

The four-stroke process that occurs in car's engine is as follows: intake, compression, power, exhaust. While the crankshaft's position, crankshaft's stroke and rod length ultimately determine where the piston will be in the cylinder at any given degree of rotation, it's the camshaft that determines the position of the intake and exhaust valve during all four strokes. An engine's camshaft is responsible for the valve timing in the engine. Proper valve timing is critical for any four-stroke automotive engine to operate at maximum efficiency. When the valves open, how high the valves open (lift), and for how long they stay open (duration) all determine the performance characteristics of the engine. In the performance symphony, the camshaft is the conductor of valve events. It orchestrates which instruments play (intake or exhaust valves), when they play (opening and closing events) and how loud they play (valve lift).

For every action, there is always a reaction. From a performance standpoint, the faster a valve opens and reaches full-lift, the better. Why? Horsepower is directly related to how much air and fuel can be stuffed into the cylinder. Air and fuel can't get into the cylinder unless the valves are open. Camshafts that quickly open the valves are said to have an aggressive lobe profile. Unfortunately, the laws of physics govern the maximum amount of possible valve acceleration or "aggressiveness." If the camshaft profile tries to accelerate the valve too fast, excessive wear or valve train problems can occur. When returning a valve to its seat, a camshaft once again cannot do this too fast or the valve slams into the valve seat (sometimes valves even bounce off the seat). Most modern cam designs optimize valve acceleration rates by designing camshafts with asymmetric lobes.

2.8 CLASSIFICATION OF CAM MECHANISM

We can classify cam mechanisms by the modes of input/output motion, the configuration and arrangement of the follower, and the shape of the cam. We can also classify cams by the different types of motion events of the follower and by means of a great variety of the motion characteristics of the cam profile. The classification of cam mechanism is based on the figure:

i. Knife-edge follower (Figure 2.4a).
ii. Roller follower (Figure 2.4b,e,f).
iii. Flat-faced follower (Figure 2.4c).
iv. Oblique flat-faced follower.
v. Spherical-faced follower (Figure 2.4d).

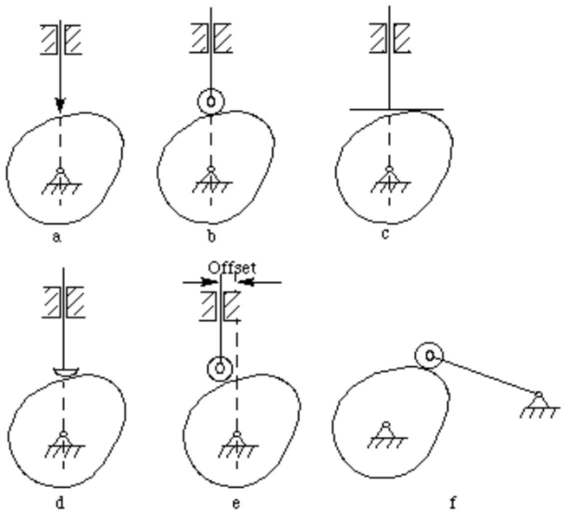

Figure 2.4: Classification of Cam Mechanism

Source: Hunt K.H (1971)

2.9 CAM SHAPE

There have variety of cam shape such as plate cam, grooved cam and end cam. The concept of the plate cam is the follower moves in a plane perpendicular to the axis of rotation of the camshaft. A translating or a swing arm follower must be constrained to maintain contact with the cam profile. This is a plate cam with the follower riding in a groove in the face of the cam according to the figure 2.5. End cam has a rotating portion of a cylinder. The follower translates or oscillates, whereas the cam usually rotates. The end cam is rarely used because of the cost and the difficulty in cutting its contour. The cams of the cam shaft are placed considering the following:

i. Sequence of the power strokes.
ii. Timing at which the valve should open in relation to the piston position.
iii. Timing at which the exhaust valve should open in relation with the timing of opening of inlet valve.
iv. Timing at which the other cylinder should start working.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

The camshaft is the most crucial part of an internal combustion engine. Its main function is to control the valve timing, thereby allowing the intake valve to open at the right time for feeding air and fuel mixture into the engine. Camshafts are basically the lobes, which are fitted in the engine of a vehicle for giving the exhaust enough time to escape out of the combustion space. Automobile uses two basic types of camshafts namely flat tappet shaft and roller tappet shaft. The other types of camshafts are race camshaft, overhead camshaft, double overhead camshaft, exhaust camshaft, and intake camshaft. The camshafts installed in automobiles are mostly constructed of modular cast iron and are induction hardened for preventing wear and tear. Other materials used for making camshafts are steel, stainless steel, copper, bronze, and brass. The different types of auto parts of camshaft include camshaft locking plates, camshaft bearing and more.

3.2 DESIGN AND MANUFACTURE OF CAMSHAFT

Design is the process by which the needs of the customer or the marketplace are transformed into a product satisfying these needs. Design is to formulate a plan for the satisfaction of a specified need and also to solve a problem. If the plan results in the creation of something having a physical reality, the product must be functional, safe reliable, competitive, manufacturability, and marketable (Shigley and Mischke, 2003).

3.3 DESIGN OF CAM PROFILE

Design of the cam profile is very crucial and it is designed on the basis of the following.

a) The distance the valve should move towards the piston.
b) The time for which the valve should remain open.
c) After the valve stays open it should take the same time for closing which it had taken while closing.

The dual lobe is used instead of the single lobe as the valve should be operated two times in one cycle. The second lobe on the cam is placed at 120º degrees from the original lobe in the direction of rotation of the camshaft.

3.3.1 Four-stroke Camshaft Profile

Figure 3.1 describe the four-stroke camshaft has a 90 degree of angle. It means the circle was divided by four thus the cam of camshaft just included there. The camshaft has two lobes, one for the intake valve and one for the exhaust valve.

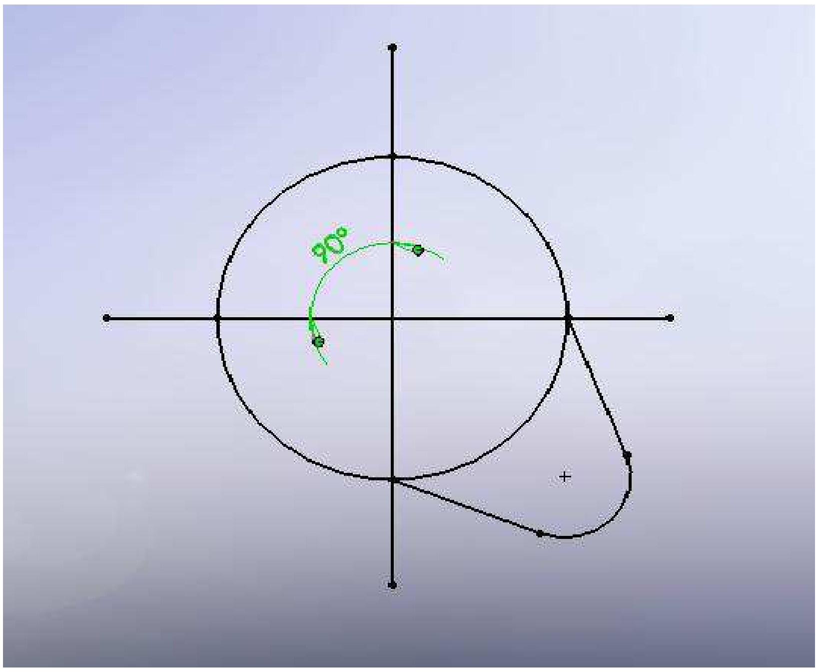

Figure 3.1: Angle of 4-stroke camshaft